PATENT APPLICATION
Docket No. D/3

APPLICATION FOR
UNITED STATES LETTERS PATENT

TO ALL WHOM IT MAY CONCERN:

Be it known that I, Robert P. Siegel residing at 52 Woodside Drive, Penfield, NY have invented:

INTELLIGENT VENTILATING SAFETY RANGE HOOD

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INTELLIGENT VENTILATING SAFETY RANGE HOOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

This disclosure relates generally to ventilating range hoods and, in particular, to a device that senses the air for the presence of certain hazardous elements and controls a variable speed fan in response to those elements, in such a way as to increase the comfort and safety of the surrounding area.

2. Background

Modern homes are being built with increasing emphasis on energy efficiency. This generally means more thermal insulation, more vapor barriers and better quality seals around windows and doors. This type of construction has given rise to the concern that ventilation may be inadequate, in light of the need for a continuous supply of fresh air and concerns about volatile byproducts of manufacturing of synthetic items. There is further concern in the many homes that use combustible fuels for heating and cooking or lighting. In addition to the psychometric comfort factors of heat and humidity and the essential need for oxygen, there are the serious health factors of carbon monoxide, smoke, and any other products of combustion deriving from these activities. Excess heat and humidity in an enclosed structure can also be quite destructive to the structure itself, leading to problems ranging from mildew, to insulation failure, to deterioration of the actual structure itself through attraction of insects and rot.

In 1998, there were approximately 200 deaths and 5000 injuries attributed to residential, non-vehicle, carbon monoxide (CO) poisoning in the US. While equipment malfunctions, such as cracked heat exchangers played a role, a key factor in all of these injuries and deaths was inadequate ventilation. Roughly 10% of these casualties have been attributed to gas stoves and ovens. Low-level cases are more difficult to track, since the symptoms are similar to common cold or flu, but are likely to have a much higher occurrence. Thus, considering the impact of lost work days and reduced activity due to illness for

low-level exposure, and the injury and death resulting from high level exposure, the cost to society of inadequate ventilation in conjunction with combustion appliances is substantial.

The ASME standards for gas stoves, which allow for trace amounts of CO, are based on the assumption that the stoves are vented. However, many are not and even those that are generally use a range hood with a fan that must be switched on manually. Many people do not turn these venting fans on unless there is detectable smoke or odor or if the kitchen becomes excessively hot. In other words, kitchens are often inadequately ventilated to a degree that may be a health and safety concern.

In the case of CO, which, being colorless and odorless is undetectable without some sort of electronic device, it is difficult to detect CO being emitted by a cooking appliance since the installation instructions for plug-in detectors recommend placing them a minimum distance away from such appliances so as to avoid setting off an alarm due to transient levels emitted from said cooking appliances. The alarms, being on/off devices must receive some minimum level of contamination before activating the alarm. The alarms are useful for notifying building occupants of the hazard although they do nothing beyond this to ameliorate the situation. The same is true for smoke detectors as well.

The device disclosed herein was invented to address these concerns, by providing an inexpensive, automated and effective response to the presence of the factors of heat, humidity, CO and smoke and smoke or other similar hazards in a kitchen as the result of cooking or introduced by some other means.

A variety of range hoods have been developed in an attempt to provide ventilation of cooking related exhaust fumes and other volatile waste products. Examples of such devices are found in U. S. Pat. Nos. 4,133,300, 4,614,177, 3,125,869 and 3,359,885. While these and other devices represent improvements in the art of ventilating heat and fumes generated by cooking food, they fail to provide the automatic safety features enabled by the current disclosure.

U. S. Pat. No. 2,807,994 to Samuel M. Bernstein, issued Oct 1, 1957 combines a ventilating range hood with an exhaust fan. US Patent 3,690,245 to Ferlise, et al, in Sept. 12, 1972 provides a range hood in which the fan can be automatically switched on when cooking is detected by means of built-in thermostats. The fan is also switched off in the presence of fire. The fan is set to switch on when the temperature in the duct exceeds 1408F which indicate that cooking is taking place. If the duct temperature exceeds 2408F, the fan is shut down on the assumption that there is a fire.

U. S. Pat. No. 5,186,260 to William Scofield, issued Feb. 16, 1993 discloses a range hood with a wire heat sensor which triggers a fire extinguisher if excessive temperatures are detected. U. S. Pat No. 5,207,276 by the same inventor, improves upon the fusible link triggering system with the use of an explosive squib.

U. S. Pat. No. 5,232,152 to Richard Tsang, issued August 3, 1993 shows a range hood connected to a humidity sensor. The fan is automatically activated if the humidity exceeds a certain preset level. The patent allows for a remotely located sensor in addition to a sensor integrated into the hood. The hood allows for both automatic and manual modes of operation.

Automatic ventilating systems that respond to temperature and humidity have been disclosed in the area of general ventilation, as well in systems that are responsive to smoke. U. S. Pat No. 6,053,809, to Henry Arceneaux, issued April, 25, 2000 automatically raises a building ceiling panel in the presence of smoke and activates an optional fan. U.S Pat. No 5,810,244 to Ngai, issued September 22, 1998 describes a ventilating fan controlled by both temperature and humidity sensors using a micro-processor controller. US Pat. No. 4,726,824 to Staten, issued February 23, 1988, describes a building level system for indoor pollution control which utilizes air quality sensors to monitor for various pollutants including carbon monoxide. The system has a display which indicates the presence of these unwanted pollutants and responds to their presence by conditioning the air by means of a variety of filters. U.S. Pat. No. 5,976,010 to Reese, et al, issued November 2, 1999 describes an energy-efficient building

level system for indoor air quality that senses the carbon dioxide level in a room and if an undesirable level is detected, actively reduces that level by mixing the air with air from other rooms.

And plug-in or battery operated smoke detectors and carbon monoxide detectors have become as popular residential safety items. U. S. Pat. No. 6,426,703 to Johnston, et al, issued July 30, 2002 describes a smoke and carbon monoxide detector that are combined and integrated into a single unit. Like the myriads of individual detectors devices available, this device will issue an alarm if either smoke or carbon monoxide is detected.

While the above-described devices are effective for their intended purpose, there is nevertheless a need, and a consumer desire, for an improved range hood that responds automatically to the various airborne hazards found in the a kitchen, particularly carbon monoxide and smoke which actively purges these hazards rather than just sounding an alarm and utilizes a smart controller to ensure the appropriate response to multiple, sometimes conflicting signals. The net result is a ventilating exhaust fan that consistently provides the appropriate operating speed as well as an alarm to be sounded if the hazard levels become dangerous despite the fan action.

SUMMARY OF THE INVENTION

Accordingly, a Smart Range Hood is disclosed that includes a sheet metal collecting hood designed to be vented outdoors, equipped with a variable speed fan, a group of air quality sensors including, temperature, humidity, carbon monoxide and smoke, and a micro-controller that determines the appropriate fan speed based on the levels detected by each of the sensors as well as the support electronics required to enable the controller to read the inputs and drive the fan. The micro-controller utilizes an algorithm that combines the output of the four sensors in order to derive an overall ventilation requirement. The ventilation requirement is then translated into a signal that initiates the appropriate fan speed, which, in turn, produces an appropriate ventilation air flow rate. If, despite the highest degree of airflow deployed in

response to a hazard condition, the detected contaminant presence remains at a hazardous level, an alarm is sounded.

The hood is also equipped with an override control which allows the user to turn the fan on to a desired level manually and to shut the fan off, under extenuating circumstances, though this is not recommended as a general practice. Display indicators are provided to indicate when the hood is responding to any of the four inputs, and at what level.

The air quality sensors, which are based on commercially available, off the shelf technology, are mounted in such a way as to sample both the air stream drawn into the hood through forced convection as well as the ambient air in the surrounding living space. The sensors will sample these air streams at periodic intervals and the algorithm will consider both the instantaneous readings as well as the trend as determined from recent history.

These and other features and advantages are described in or apparent from the following detailed description of the exemplary embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features of the exemplary embodiments will be apparent and easily understood from a further reading of the specification, claims and by reference to the accompanying drawings in which like reference numerals refer to like elements and wherein:

FIG. 1 is a front view of a Smart Range Hood apparatus;

FIG. 2 is a bottom view of a Smart Range Hood apparatus;

FIG. 3 is a simple flow chart illustrating the controller function.;

FIG. 4 is a chart showing the weighted membership functions for the fuzzy logic control algorithm for the Temperature input.

FIG. 5 is a chart showing the weighted membership functions for the fuzzy logic control algorithm for the Humidity input.

FIG. 6 is a chart showing the weighted membership functions for the fuzzy logic control algorithm for the Carbon monoxide level input.

FIG. 7 is a chart showing the weighted membership functions for the fuzzy logic control algorithm for the Smoke input.

DETAILED DESCRIPTION OF THE INVENTION

While preferred embodiments will be described hereinafter, it will be understood that it is not intended to limit the disclosure to those embodiments. On the contrary, it is intended to cover all alternatives, modifications, and equivalents as may be included within the spirit and scope of the disclosure as defined by the appended claims.

For a general understanding of the features of the exemplary embodiments, reference is made to the drawings. In the drawings, like reference numerals have been used throughout to identify identical elements. **FIGS. 1 – 7** schematically depict various views illustrating an improved range hood incorporating the features of the present invention therein including description of the control scheme which is essential to its operation. It will become evident from the following discussion that the disclosed range hood may be employed in a wide variety of applications for ventilating habitable spaces and is not specifically limited in its application to the particular apparatus and method specifically mentioned herein.

Referring now to **FIGS. 1** and **2**, various views are shown illustrating the Smart Range Hood **10**. In **FIG. 1**, a sheet metal enclosure commonly known as a hood **11** connects to external venting ductwork through a plenum adapter **12.** It contains a series of openings **14** through which the various air quality sensors **13** can be exposed to air in the ambient environment as well as to the air that is being drawn up through the ductwork by the fan **20** of **FIG. 2** and through plenum adapter **12.** Alternatively, the fan could be attached to the ductwork on the outside of the structure being ventilated, if desired. A series of indicators **15**, one each corresponding to the sensors, displays the status of the ventilating system with regard to the current level of each hazard. It is envisioned that a green indication will reflect a level of that particular hazard that is within acceptable limits. A yellow indication will reflect that a hazard condition has been detected and that remediation, in the form of ventilating airflow, is underway. A red indication reflects the fact that the hazard has reached a dangerous level despite the remediating airflow and that evacuation or other

emergency action should be taken. If this condition should persist for more than a few seconds, an audible alarm **19** is sounded. The combination of the red indictor and the audible alarm will inform the occupants as well as emergency personnel as to the cause of the alarm. While the primary operation is automatic, a number of manual controls are provided to be used in the manual mode. A light switch **16** allows the user to control the light. A second switch **17** allows the user to switch the fan operation between manual and automated modes. In manual mode, the smart range hood behaves in a manner that is identical to a conventional range hood. A rotary speed control **18** is provided for use when the Smart Range Hood is operating in manual mode. It bears repeating that while this is a preferred embodiment of the Smart Range Hood and its appearance and user interface, there are many variations possible that reflect the same underlying concept.

FIG. 2 shows the Smart Range Hood, when viewed from underneath **FIG 1**. In this view, the variable speed fan **20** is shown. This fan has been selected for its variable speed operation and its high volume of airflow under the operating conditions typical of a ducted exhaust fan where pressure drops would be those associated with ducting and filter losses. Flow rate would range from several hundred cubic feet per minute (cfm) to a thousand cfm or more depending on the requirement for a particular model. The air quality sensors **13** can also be seen in this view since they protrude into the air stream enabling them to sample air from the stream of air being exhausted as well as the ambient air in the room. An overhead light **21** is also shown.

FIG. 3 is a block diagram illustrating the top-level control function. The output signals from the four air quality sensors: smoke **30**, carbon monoxide **31**, temperature **32** and humidity **33**, initiated by sampling block **38,** are fed into the signal conditioning front end circuitry **35** of the micro-controller **36**. This circuitry provides a time base, sample clocking, filtering, amplification and scaling as necessary as well as analog-to-digital conversion. At each scheduled request, the signals enter this stage as noisy, non-scaled, analog voltages and leave as essentially clean, time-stamped digital representations of the level of each of the

four inputs. The micro-controller **36** stores several readings in a memory buffer **37** as a means of defining recent history. This is used to dynamically determine if the level of each of the four inputs is increasing, decreasing or remaining the same. The micro-controller **36** then applies the embedded control algorithm which examines the composite output of the four sensors as well as the trend information and determines from them an instantaneous ventilation requirement. The ventilation requirement is then displayed on the indicators **15** for each of the factors. The net result is then fed as a control signal to the power supply **39** which provides the driving voltage to regulate the fan speed **40**, if a DC fan is used, or, if a pulse-width-modulated control scheme is used, the ventilation requirement result is translated into a PWM duty cycle which will, in turn, drive the fan at the appropriate speed.

While the present disclosure can potentially be implemented with a variety of control schemes that integrate the output signals of any number of air quality sensors to determine a ventilation requirement and drive the fan accordingly, the preferred embodiment described herein is shown with a fuzzy logic controller. Fuzzy logic control is convenient because it allows microprocessor control to be applied in areas where an explicit mathematical model does not exist or is not known. Instead, the math model is replaced by a set of heuristic, or experiential rules, that can be converted to mathematical form through a process called fuzzification. Thus, a controller of this sort can be constructed based on rules of the following (simplified) form:

If CO level is HAZARD, turn fan on to MAXIMUM speed.

If Smoke level is HEAVY SMOKE, turn fan on to MAXIMUM speed.

If Temperature is WARM and Humidity is HUMID, turn fan on LOW.

If Temperature indicates FIRE, then turn fan OFF.

The development of a Fuzzy Logic Controller (FLC) requires three distinct steps:

(1) the fuzzification of input values where specific values of the controller inputs are mapped to the linguistic labels by means of the membership

functions

(2) a set of fuzzy if-then inferencing rules are developed which define relationship between the inputs and the outputs

(3) a defuzzification process which converts the output labels selected by the application of the inputs to the rules back into numerical values.

Fuzzy logic differs from Boolean logic in that statement can be both true and false to a certain degree. Thus if the temperature is somewhere between warm and hot, the statement, the temperature is warm, may be 30% true, and the statement, the temperature is hot, may be 70% true. In this case the resulting action would be a weighted average between the response for warm and the response for hot. The membership functions map the degree of membership of each parameter to the associated linguistic labels such as warm, hot, etc. **FIG. 4** is the membership function for temperature. From this we can see that anything up to 90° is considered warm and everything between 130° and 170° is considered hot. Between 90° and 130°, the temperature is both warm and hot to varying degrees as displayed by the function, which in this case is linear. Similarly, at 195° the temperature is considered very hot, which would call for even higher fan speed. Between 170° and 195°, the temperature is both hot and very hot to varying degrees according to the linear function shown. But at 240°, it is assumed that a fire is taking place. In this case, the fan is turned off and the alarm is sounded.

FIG. 5 shows the membership function for humidity. Humidity in a cooking environment is expected to be high. Anything below 50% is considered normal, meaning no additional ventilation is required. Between 50 and 70% it is becoming humid. Between 70 and 80% is considered humid. Between 80% and 95% is becoming very humid. Anything above 95% RH is very humid. Note that these values are illustrative of one particular implementation. Other implementations are possible and may be desirable under certain conditions, for example, in high altitude areas, or areas of extremely dry or wet climate.

FIG. 6 shows the membership function for smoke. This is measured in obscuration%. Anything below 0.01% is considered pure air. Between 0.01 and

0.1% is considered incipient smoke. Anything above 0.1 is considered visible smoke and anything above 1.0% is considered heavy smoke.

FIG. 7 shows the membership function for CO in parts per million (PPM). Here we have only three levels, none, low and hazard. That is because only a very low level of CO is considered tolerable. Anything between 2 and 9 PPM is considered low and anything above 35 is considered hazardous.

The complete rules are of the form:

If Temperature is A and Humidity is B and Carbon Monoxide is C and Smoke is D; then Fan Speed is E. These are shown in the following tables: Since there are four levels of temperature, three levels of humidty, four levels of smoke and three levels of CO, that results in a total of 144 rules. For example, the first rule would read: If the Temperature is Warm, the Humidity is Normal, Smoke is Normal, and CO is None: there is no need for ventilation and the fan speed should be set to OFF. However, in the next rule, where the CO level moves up to Low, the fan speed is set to HIGH, to attempt to flush the contaminant out.

These rules should be taken as initial settings. Additional rules can be added to consider the current trend as mentioned earlier. If, for example, in the previous case, the CO level remains at Low for some time, without dropping back to None, the fan speed should be increased until there is no detectable trace of contaminant.

Rule #	Temperature	Humidity	Smoke	CO	Fan
1	Warm	Normal	Normal	None	**Off**
2	Warm	Normal	Normal	Low	**High**
3	Warm	Normal	Normal	Hazard	**Maximum**
4	Warm	Normal	Incipient	None	**Medium**
5	Warm	Normal	Incipient	Low	**High**
6	Warm	Normal	Incipient	Hazard	**Maximum**
7	Warm	Normal	Visible	None	**High**
8	Warm	Normal	Visible	Low	**High**
9	Warm	Normal	Visible	Hazard	**Maximum**
10	Warm	Normal	Heavy	None	**Maximum**
11	Warm	Normal	Heavy	Low	**Maximum**
12	Warm	Normal	Heavy	Hazard	**Maximum**
13	Warm	Humid	Normal	None	**Low**
14	Warm	Humid	Normal	Low	**High**
15	Warm	Humid	Normal	Hazard	**Maximum**
16	Warm	Humid	Incipient	None	**Medium**
17	Warm	Humid	Incipient	Low	**High**
18	Warm	Humid	Incipient	Hazard	**Maximum**
19	Warm	Humid	Visible	None	**High**
20	Warm	Humid	Visible	Low	**High**
21	Warm	Humid	Visible	Hazard	**Maximum**
22	Warm	Humid	Heavy	None	**Maximum**
23	Warm	Humid	Heavy	Low	**Maximum**
24	Warm	Humid	Heavy	Hazard	**Maximum**
25	Warm	Very Humid	Normal	None	**Medium**
26	Warm	Very Humid	Normal	Low	**High**
27	Warm	Very Humid	Normal	Hazard	**Maximum**
28	Warm	Very Humid	Incipient	None	**Medium**
29	Warm	Very Humid	Incipient	Low	**High**
30	Warm	Very Humid	Incipient	Hazard	**Maximum**
31	Warm	Very Humid	Visible	None	**High**
32	Warm	Very Humid	Visible	Low	**High**
33	Warm	Very Humid	Visible	Hazard	**Maximum**
34	Warm	Very Humid	Heavy	None	**Maximum**
35	Warm	Very Humid	Heavy	Low	**Maximum**
36	Warm	Very Humid	Normal	Hazard	**Maximum**

Table 1: Fuzzy Rules for Temperature=Warm

Rule #	Temperature	Humidity	Smoke	CO	Fan
37	Hot	Normal	Normal	None	**Low**
38	Hot	Normal	Normal	Low	**High**
39	Hot	Normal	Normal	Hazard	**Maximum**
40	Hot	Normal	Incipient	None	**Medium**
41	Hot	Normal	Incipient	Low	**High**
42	Hot	Normal	Incipient	Hazard	**Maximum**
43	Hot	Normal	Visible	None	**High**
44	Hot	Normal	Visible	Low	**High**
45	Hot	Normal	Visible	Hazard	**Maximum**
46	Hot	Normal	Heavy	None	**Maximum**
47	Hot	Normal	Heavy	Low	**Maximum**
48	Hot	Normal	Heavy	Hazard	**Maximum**
49	Hot	Humid	Normal	None	**Low**
50	Hot	Humid	Normal	Low	**High**
51	Hot	Humid	Normal	Hazard	**Maximum**
52	Hot	Humid	Incipient	None	**Medium**
53	Hot	Humid	Incipient	Low	**High**
54	Hot	Humid	Incipient	Hazard	**Maximum**
55	Hot	Humid	Visible	None	**High**
56	Hot	Humid	Visible	Low	**High**
57	Hot	Humid	Visible	Hazard	**Maximum**
58	Hot	Humid	Heavy	None	**Maximum**
59	Hot	Humid	Heavy	Low	**Maximum**
60	Hot	Humid	Heavy	Hazard	**Maximum**
61	Hot	Very Humid	Normal	None	**Medium**
62	Hot	Very Humid	Normal	Low	**High**
63	Hot	Very Humid	Normal	Hazard	**Maximum**
64	Hot	Very Humid	Incipient	None	**High**
65	Hot	Very Humid	Incipient	Low	**High**
66	Hot	Very Humid	Incipient	Hazard	**Maximum**
67	Hot	Very Humid	Visible	None	**High**
68	Hot	Very Humid	Visible	Low	**High**
69	Hot	Very Humid	Visible	Hazard	**Maximum**
70	Hot	Very Humid	Heavy	None	**Maximum**
71	Hot	Very Humid	Heavy	Low	**Maximum**
72	Hot	Very Humid	Normal	Hazard	**Maximum**

Table 2: Fuzzy Rules for Temperature=Hot

Rule #	Temperature	Humidity	Smoke	CO	Fan
73	Very Hot	Normal	Normal	None	**High**
74	Very Hot	Normal	Normal	Low	**High**
75	Very Hot	Normal	Normal	Hazard	**Maximum**
76	Very Hot	Normal	Incipient	None	**High**
77	Very Hot	Normal	Incipient	Low	**High**
78	Very Hot	Normal	Incipient	Hazard	**Maximum**
79	Very Hot	Normal	Visible	None	**High**
80	Very Hot	Normal	Visible	Low	**High**
81	Very Hot	Normal	Visible	Hazard	**Maximum**
82	Very Hot	Normal	Heavy	None	**Maximum**
83	Very Hot	Normal	Heavy	Low	**Maximum**
84	Very Hot	Normal	Heavy	Hazard	**Maximum**
85	Very Hot	Humid	Normal	None	**Medium**
86	Very Hot	Humid	Normal	Low	**High**
87	Very Hot	Humid	Normal	Hazard	**Maximum**
88	Very Hot	Humid	Incipient	None	**High**
89	Very Hot	Humid	Incipient	Low	**High**
90	Very Hot	Humid	Incipient	Hazard	**Maximum**
91	Very Hot	Humid	Visible	None	**High**
92	Very Hot	Humid	Visible	Low	**High**
93	Very Hot	Humid	Visible	Hazard	**Maximum**
94	Very Hot	Humid	Heavy	None	**Maximum**
95	Very Hot	Humid	Heavy	Low	**Maximum**
96	Very Hot	Humid	Heavy	Hazard	**Maximum**
97	Very Hot	Very Humid	Normal	None	**High**
98	Very Hot	Very Humid	Normal	Low	**High**
99	Very Hot	Very Humid	Normal	Hazard	**Maximum**
100	Very Hot	Very Humid	Incipient	None	**High**
101	Very Hot	Very Humid	Incipient	Low	**High**
102	Very Hot	Very Humid	Incipient	Hazard	**Maximum**
103	Very Hot	Very Humid	Visible	None	**High**
104	Very Hot	Very Humid	Visible	Low	**High**
105	Very Hot	Very Humid	Visible	Hazard	**Maximum**
106	Very Hot	Very Humid	Heavy	None	**Maximum**
107	Very Hot	Very Humid	Heavy	Low	**Maximum**
108	Very Hot	Very Humid	Normal	Hazard	**Maximum**

Table 3: Fuzzy Rules for Temperature= Very Hot

Rule #	Temperature	Humidity	Smoke	CO	Fan
109	Fire	Normal	Normal	None	**Off**
110	Fire	Normal	Normal	Low	**Off**
111	Fire	Normal	Normal	Hazard	**Off**
112	Fire	Normal	Incipient	None	**Off**
113	Fire	Normal	Incipient	Low	**Off**
114	Fire	Normal	Incipient	Hazard	**Off**
115	Fire	Normal	Visible	None	**Off**
116	Fire	Normal	Visible	Low	**Off**
117	Fire	Normal	Visible	Hazard	**Off**
118	Fire	Normal	Heavy	None	**Off**
119	Fire	Normal	Heavy	Low	**Off**
120	Fire	Normal	Heavy	Hazard	**Off**
121	Fire	Humid	Normal	None	**Off**
122	Fire	Humid	Normal	Low	**Off**
123	Fire	Humid	Normal	Hazard	**Off**
124	Fire	Humid	Incipient	None	**Off**
125	Fire	Humid	Incipient	Low	**Off**
126	Fire	Humid	Incipient	Hazard	**Off**
127	Fire	Humid	Visible	None	**Off**
128	Fire	Humid	Visible	Low	**Off**
129	Fire	Humid	Visible	Hazard	**Off**
130	Fire	Humid	Heavy	None	**Off**
131	Fire	Humid	Heavy	Low	**Off**
132	Fire	Humid	Heavy	Hazard	**Off**
133	Fire	Very Humid	Normal	None	**Off**
134	Fire	Very Humid	Normal	Low	**Off**
135	Fire	Very Humid	Normal	Hazard	**Off**
136	Fire	Very Humid	Incipient	None	**Off**
137	Fire	Very Humid	Incipient	Low	**Off**
138	Fire	Very Humid	Incipient	Hazard	**Off**
139	Fire	Very Humid	Visible	None	**Off**
140	Fire	Very Humid	Visible	Low	**Off**
141	Fire	Very Humid	Visible	Hazard	**Off**
142	Fire	Very Humid	Heavy	None	**Off**
143	Fire	Very Humid	Heavy	Low	**Off**
144	Fire	Very Humid	Normal	None	**Off**

Table 4: Fuzzy Rules for Temperature= Fire

Notice that certain inputs dominate the rules as common sense dictates. For example, as Table 4 shows, if Fire is detected, the fan is shut off regardless of what the other inputs are. Likewise, in all cases not involving a fire, if smoke is Heavy or if CO is at the Hazard level, the fan is set to Maximum, regardless of the other inputs. This set of rules is shown as an illustrative example of a workable embodiment of the disclosure. Other rules sets can be proposed that also embody the underlying disclosure but may be preferable in some cases.

The next step is to mathematically define the linguistic labels for fan speed, which will allow us to convert the rule outcomes to numerical values.

Label	% of Maximum Speed
Off	0
Low	25
Medium	50
High	75
Maximum	100

Table 5: Definition table for Fan Speed Output

We are now ready to defuzzify. To see how this would work, consider the following example. The Smart Range Hood is installed in kitchen. A meal is cooking. The temperature at the hood is 110° F. The relative humidity is 74%. Smoke is 0.08% visible obscuration and CO level is 0 ppm. Referring to the membership functions, we can see that the temperature of 110° F is halfway between 90° and 130°, which means it has a membership of 0.5 in Warm and 0.5 in Hot. The RH @ 74% is 1.0 in Humid. Smoke @ 0.08% has a membership of 0.8 in visible smoke and 0.2 in incipient smoke and CO @ 0 ppm represents a membership of 1.0 in None. This would invoke the following four rules: 17,19,52 and 55. This can be best shown in the following Defuzzification Table.

Rule	Temperature	Humidity	Smoke	CO	Output
17	0.5	1.0	0..2*	1.0	Medium
19	0.5*	1.0	0.8	1.0	High
52	0.5	1.0	0.2*	1.0	Medium
55	0.5*	1.0	0.8	1.0	High

Table 6: Defuzzification Table for Example

Note that the lowest value for each input has an asterisk. The lowest value drives each rule.

So Rule 17, which has an output of Medium or 50% of full speed is driven by a weight of 0.2 and Rule 19, which has an output of High, or 75%, is driven by a weight of 0.5.

So our result is:

(0.2) *(.5) + (.5) *(0.75) =0.475 or 47.5% of maximum speed.

Rules 52 and 55 are not used in this case, since the Medium and High outputs were already represented by the first two rules.

As noted earlier, certain values, such as hazardous levels of either smoke or CO will override this algorithm and turn the fan immediately on at maximum. If the sensor levels do not drop to a lower level within a period of approximately one minute, the audible alarm will be sounded.

In summary, a system has been disclosed that senses the air in and around a range hood for the presence of particular hazardous elements and activates an exhaust fan to purge those elements to ensure a safe and healthy indoor environment. The system includes a collecting hood, a variable speed exhaust fan, a series of sensors capable of detecting the presence of various hazardous elements including, but not limited to, temperature, humidity, carbon monoxide and smoke, a controller capable of integrating the signals from the various sensors and deriving from them a ventilation requirement, the support electronics necessary to drive the fan in accordance with said ventilation requirement, a means of display to indicate the presence of each of the hazardous elements and an audible alarm that can be activated if excessively hazardous levels are detected.

It will be apparent to those skilled in the art that various modifications and variations can be made in the disclosed method and apparatus without departing from the spirit and scope of the disclosure. Other embodiments of the disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the disclosure. It is intended that the specification and the disclosed means be considered as exemplary only, with the full scope of the disclosure being defined by the following claims.